02 May 2013, 4:00 pm - 6:00 pm

# Case Studies on Application of Coir Geotextiles for Soil Stabilization

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Commemorate the Legacy of Ralph B. Peck
April 29 - May 4, 2013 CHICAGO
Seventh International Conference on Case Histories in Geotechnical Engineering
and Symposium in Honor of Clyde Baker

# CASE STUDIES ON APPLICATION OF COIR GEOTEXTILES FOR SOIL STABILIZATION

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## ABSTRACT

Coir geotextiles (Coir Bhoovastra) is one of the non-traditional highly demanded and promising coir product with multi usages as eco-friendly, sustainable and substitutable product for many Civil Engineering applications especially in Geotechnical Engineering. Coir Geo-textiles is an emerging area of coir industry. Kerala, the major coir producing state in India is fast growing in the development and application of Coir geotextile. Coir Geotextile development program is also intended to popularize the coir products as geotextile material in National & international level and to provide internationally accepted standardization for coir geotextile. The use of Coir geotextile is well established in areas of erosion control, blanket drains and as vertical drains. As the synthetic geotextile are non biodegradable, the natural geosynthetics, especially coir geotextile are increasingly preferred. Experimental studies have proved that while cotton and jute degrade within six months, coir geotextile provide good support on slopes for about 5 years. It is resistant to saline water. Its greatest advantage is that it provides an ecological niche for a rapid re-establishment of the vegetation cover. Coir resembles natural soil in its capacity to absorb solar radiation. Coir mesh mattings are used extensively in erosion control works. Coir geotextile are also used as reinforcement and separator between sub grade and base course. This paper intend to review the available published case studies in this area along with the study of a case of about 1.5 km farm road constructed using coir geotextile in Kerala
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## INTRODUCTION

Coir geotextiles with its Indianised connotation "Coir Bhoovastra", is a geosynthetic made from the coconut fibre extracted from the husk of the coconut fruit. Being a technology based product, like their polymeric counter parts, coir geotextiles can be synthesized for specific application in geotechnical engineering practice. A range of different mesh matting is available, meeting varying requirements. Coir fibres can be converted into fabric both by woven and non woven process. Coir mesh matting of different mesh sizes are most established coir geotextiles, under quality code numbers H2M1 to H2M10. These qualities represent coir geotextiles of different mesh sizes ranging from 1/8" to 1". Several types of non-woven geotextiles also exist. Most non-woven mats are made from loose fibres, which are interlocked by needling or rubberizing. Non-woven geotextiles are available in several dimensions and have a minimum thickness of 2mm.

Coir geotextiles are eminently suitable for many Civil Engineering applications, which are not yet perceived by most engineers. Majority of geosynthetics used in Civil Engineering applications are polymeric. These products generally have a long life and do not undergo biological degradation, but are liable to create environmental problems in the long run. The use of biodegradable natural material in non-critical civil engineering applications has gained popularity throughout the world due to the growing awareness of the sustainable development to preserve the environment.

## POTENTIALITIES

Coir, which is increasingly being accepted the world over as an eco-friendly, natural resource, is a versatile product. The products made out of it and its application area varies widely right from the coir yarn to coir geotextiles. Besides being foremost among traditional ones, coir industry in India has been cottage based and hence employment oriented. Kerala is one of the main center of coir industry accounting for 42% of total production, providing sustenance to 3.5 lakhs families in the area of costal belt, out of which, 80% are women living mostly below poverty line. Coir Geotextile is an emerging product of coir industry. This is one of the non-traditional highly demanded and promising coir product with multi usages as eco-friendly, sustainable and substitutable product for many Bio- engineering and Civil Engineering and applications especially in Geotechnical Engineering.

Coir geotextiles can be easily blended with man-made fibres and other natural fibres to get wide range of products. Its low cost makes it attractive for geotechnical applications. The major drawback is its biodegradability. However this very fact can be used to advantage in creating environmental friendly applications. The potential application areas of coir geotextile in civil engineering are erosion control, slope protection, embankments, wasteland development, road underlays, road edge drains, ground improvement, reinforcements etc. Studies conducted in geo-textiles have indicated that coir is better preferred, as compared to jute or other natural material owing to certain characteristics like durability, strength, hairy surface etc.. It enables vegetation to take root on the applied area thus making the bonding of the soil very strong. They are ideal for application on hill slopes, road and rail embankments [Beena, 2010]

## PRODUCT RANGE

Coir geo-textiles have been emerging as excellent media for soil bio-engineering applications in many parts of the world in the form of Meshes, Netting, Needle Felts & Pads, Erosion Control Blankets, Geo Rolls, Vegetation Fascines, Geo Cushions, Geo Beds, Anti-weed Blankets and so on. It is being extensively employed to combat a variety of environmental challenges.

## APPLICATIONS

Coir geotextiles finds application in a number of situations in geotechnical engineering practice. Coir geotextiles can be used as an overlay or interlay- the former protecting the surface from runoff and the later performing the functions of separation, reinforcement, filtration and drainage. Soil bio-engineering with coir geotextiles finds effective application in the following soil situations.

- Separation application in unpaved roads, railways, parking and storage areas
- Shore line stabilization
- Storm water channels
- Slope stabilization in railway and highway cuttings and embankments
- Water course protection
- Reinforcement of unpaved roads and temporary walls
- Providing sub base layer in road pavement
- Filtration in road drains and land reclamation
- Mud wall reinforcement
- Soil stabilization

Some of the major application areas are detailed below [Babu, 2007].

### Unpaved roads

Unpaved roads are mainly low volume roads constructed in rural areas. The unsatisfactory performance of roads arises from main two factors. These are poor quality of subgrades and insufficient thickness and quality of sub base and base courses. All these factors can be mitigated by the use of coir geotextiles either alone or in conjunction with other products/ materials. In cohesion less soil lateral confinement by coir geotextiles will be able to improve the shear resistance and bearing capacity and consequently reduces the thickness of the pavement material. In cohesive soils adequate drainage of the subgrade can be created by depressing the water table by use of coir geotextile drains and hence enhanced bearing capacity. In very poor soil the use of coir geotextile composite blankets and strip drains can help in quickening consolidation of non-expansive clays and reducing construction time of high embankments. Coir geotextiles can also be used in pavement layer to reduce thickness, increase fatigue resistance and reduce reflection cracking due to traffic.

### Embankment construction in poor soils

The problem of construction of bunds in marshy areas is improvement of low shear strength of soil to support soil fill of required height. Coir geotextiles can be used both for foundation support and also in the fill particularly for filter and separation function so that erosion of the sides can be prevented. Coir fibres are effective in preventing failures due to reversal of pore pressures, through drainage without removal of soil particles. Also with the provision of reinforcements, the compaction of the side faces can be improved which otherwise cannot be taken to edges.

### Retaining walls

Retaining walls are conventionally built to withstand lateral pressure of soil fill through the action of gravity, which involves additional vertical force. This necessitates a strong foundation or large base width and hence costly. Coir geotextiles can be used in the fill itself so that no additional wall is required to resist the lateral pressure. This is particularly suited to walls having low height and foundation soil is weak. Hence larger heights with surcharge are not advisable to construction with coir geotextiles as the tensile strength of this product is less than what is required.

### French drains

These are drainage measures for subgrade soil to lower the water table to protect road formations without the use of slotted pipes to take the collected water. Coir geotextiles with high transmittivity like needled felt with mesh core can be used in the place of pipes and thicker layers can be used to reduce the quantity of pervious sand surrounding the drain.

Vertical drains

Construction of embankments foundation in soft and sensitive clays requires accelerated consolidation. Several methods such as sand drains, metal drains, geosynthetic PVDs etc. are used. Instead of this coir geotextiles can be used. Even if the coir decays, in course of time, the initial period helps in consolidation and temporary support and long-term stability is not affected.

## CASE STUDIES IN LITERATURE

Though less in number compared to polymeric geotextiles, coir geo textiles have been tried for different civil engineering application. Few case studies reported in literature are described below (Ayyar et. al., 2002).

### Protection of mine waste dump in Goa

All most all mines in Goa are facing the perennial problem of dumping of mine waste from iron ore mines. Since the density of these free dumped materials are very low, severe surface erosion takes place along the open mine waste dumps during the monsoon season and creates a lot of environmental problems in the surrounding area. Also the large gullies formed due to the rain can cause deep seated failure. In order to prevent the surface erosion and to increase the slope stability of the waste dumps, coir geotextiles were tried. Instead of the traditional method of planting acacia plants or cashew plants over a small cover of lateritic soil (which is scarce and to be transported), application of new generation coir erosion control blankets with special design features could be an effective alternative to provide solutions and speed up the vegetation process.

Coir geotextiles used was a nonwoven type with medium thick polypropylene net on top and bottom and having a tensile strength of 3.5 kN/m. Wooden planks of 25 mm thick and having a length of more than 1000 mm were used to fix the geotextile in position. Length of the planks was so selected that it case to cut the probable slip circle at top and bottom region of the slope. The sites treated with the blankets are performing satisfactorily with stabilization of the slopes, controlling the soil loss, reduction in pollution and also in assisting establishment.

### Pullangode estate erosion control

One of the successful stories of using coir fabrics to control the severe erosion of a slope of a rubber plantation area in Nilambur, Kerala has been reported by Rao and Balan (2000). An area of 583m$^2$ (20x31) over a slope 49-66$^0$ of 50m length, which suffered severe erosion and the abandoned plantation in the preceding three decades with wide gullies presented an ideal area for the study.

Two varieties of coir mattings manufactured by Aspinwall, $H_2M_8$ and $H_2M_6$ were used. Rolls of the coir matting were first anchored in the top trench and then unrolled along the slope. Overlaps of 15cm minimum between adjacent ones were given. Mild steel staples were used in a grid pattern of 2m spacing to anchor the matting to the ground. Coir ropes 20mm diameters were used to tie the coir matting in a criss cross pattern at 90$^0$ making a grid of 1m size.

A highlight of this study is the fact that the soil protected is lateritic (with high acidity low p$^H$) and peniseltum purpureum grass was adopted which is suitable for high elevations and steep slopes. Also it was noticed that coir mesh mattings of smaller aperture were more effective than the areas with coarse openings.

### Accelerated construction of Calicut bypass

A stretch of road in NH 17 bypass consists of road embankments running across paddy fields near Ramanattukara in Calicut. Embankments of upto 3.5m had to be constructed with top width of 12m on soil with very low shear strength and high compressibility. The natural water content of clay was close to liquid limit with undrained shear strength of 6kPa. This meant that embankments of height more than 1.2m height could not be constructed without ground improvement. Acceleration of ground improvement was a key factor in the timely execution o construction.

The method adopted was to install vertical drains of 25cm diameter at 2m c/c in a triangular pattern upto 5m depth. Crushed stone aggregate was used to fill the drain. The top of all drains were suitably covered to prevent clogging till the horizontal drainage blanket was laid. A drainage blanket of 40mm crushed stone was spread and compacted to a thickness of 20 cm. A layer of nonwoven coir needle felt of 1000gm/m$^2$ was used to reinforce the blanket and confine it transversely and ends folded at the end of width, so that confinement and drainage were effective. Split bamboo strips placed transversely will also aid in the rigidity of the base. The construction was very effective in reducing the time for settlement shear strength improvement.

### Coir for erosion protection in Western countries

Utilization of woven Coir Geotextiles for environmental protection has been reported by Schurholz [1991]. One of the cases is re-vegetation of a shoreline in Lake Bodensee which is a triangular border of Switzerland, Austria and Germany. Due to increased water pollution and wave action, reed belts along the shore line were reduced. Coir geotextile fencing was designed for the area where there was a high fluctuation in water level during summer and winter. Initially, 60 -75 cm wooden stakes were driven into the ground and the stabilization fencing was attached vertically on these stakes, using nails and staples. These stakes should be sufficiently anchored in ground and the geotextile should be anchored into a trench to prevent run off beneath the fence.

Another case study reported by Schurholz [1991] is that of Stabilization of river bank in West Germany. The section of a 700m of the bank and transitional zone between the bank and river bed was severly damaged by flooding. Coir fabric was used to repair this bank. The geotextile was extended from the rock, which was already there, to the top of the bank for a height of 4 to 5m in 1:1 slope. The geotextiles were entrapped in trenches at top and bottom. Vegetation was provided over the fabric to have a living bush layer system.

## CASE STUDY OF CONSTRUCTION OF 1.4KM LONG FARM ROAD IN CHANGARAM PADASEKHARAM, THURAVOOR, KERALA

Kerala is a land which is rich in backwaters and coastal area, and the nearby people in this region are farmers and fishermen. Hence small farm roads across the paddy fields and prawn growing ponds (locally known as Chemmien Kettu) is a common sight in Kerala. Here the design and construction details of such a farm road using coir geotextiles are discussed. The Kerala Land Development Corporation was the executing agency of the work which is named as "Construction of farm road at Vallethodu Pulintharamuri and Changaram Padasekharam south bund starting from Cherungal Bridge". The agency approached Cochin University of Science and Technology for the Technical guidance for the work.

## SITE CHARACTERISTICS

The length of the proposed farm road is 1.405 km. The bund, over which the farm road is proposed, aligned through paddy fields. On one side of the bund, there exists a small canal (thodu) and other side it is fish pond (`Chemmeenkettu`), which will be seasonally converted to paddy field for Pokkali farming. Hence water exists on either side of the bund almost throughout the year. During the rainy season the water may reach the top level of the bund. For the improvement of the agricultural and industrial facilities and also for the development of the local people living near locality, the widening of the bund and forming a farm road became necessary.

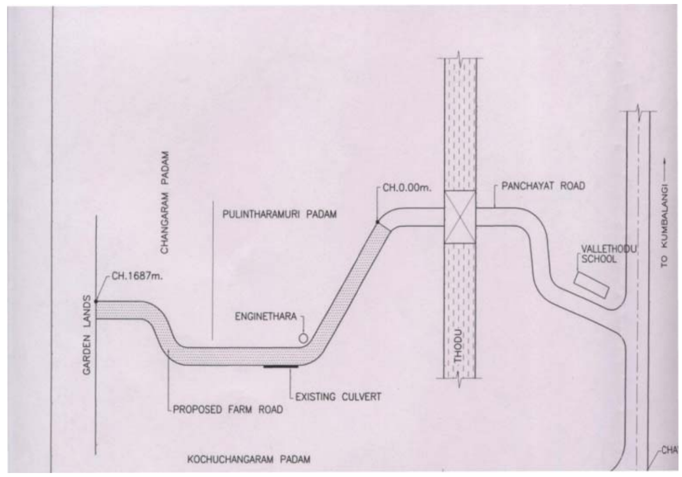


*Fig.1. Site plan and location map*

The site visit during March 2006, which was a summer season, it was observed that water still exist in the mud canal (having width 3.5m approximately), and also in the fish farm pond. The bund was expected to become dry in condition by last week of March. Along the proposed farm road, there are 4 curves in the alignment. The height of the existing bund as supplied by KLDC was 1.3m and the bund is required to be raised to 2.2m in order to form the farm road. It is found that the bund is partially filled by locally available red earth.

*Fig.2. Photograph of partially filled bund*

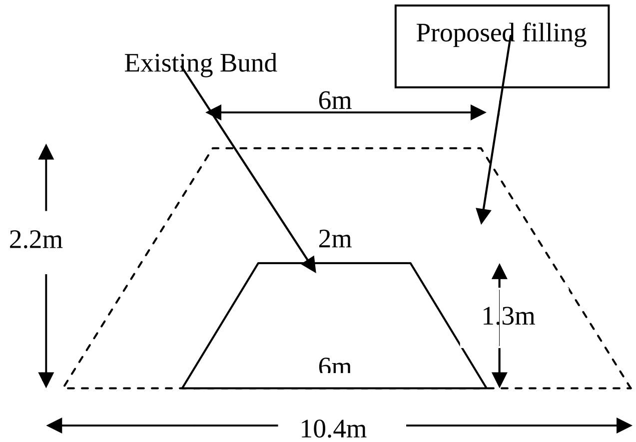


Fig.3. Typical cross section of existing bund and proposed filling

## TESTING AND ANALYSIS

Soil samples bought to the laboratory was tested for its engineering properties like particle size distribution, specific gravity, density, Atterburg's limit etc., as per the current Indian Standard Specification in the Geotechnical Engineering Laboratory of the institute. The existing bund is of clayey soil with liquid limit= 120% and a plasticity index of 59%. The unit weight of the soil was found to be 13kN/m3 and having a cohesive strength of 10kN/m2. Red earth having an optimum moisture content of 21% and Maximum dry density of 16kN/m3 was used for the formation of the embankment. The uniformity Coefficient and effective grain size of the red earth material was found to be 2.57 and 0.67mm. Trial sections are considered and both internal and external stability analyses were conducted.

## DESIGN RECOMMENDATIONS

Based on the test results and the stability analyses, a typical section of the reinforced embankment was recommended as shown in Fig.4, with two layers of coir geotextiles [Beena, 2006]. Frictional or cohesive frictional fill and which are easy to compact and also relatively free draining material is recommended for the fill. The earth filling should be having a minimum dry density of 15kN/ $m^3$. The Coir Geotextiles recommended for use is H2M8 having the following minimum properties:

| | |
|---|---|
| Mesh opening (mm) | = 6 x 10.5 |
| Thickness at 2 kPa | = 10mm |
| Mass per unit area | = 900 gm per square meter |
| Wide width Tensile strength | = 24 kN/m |

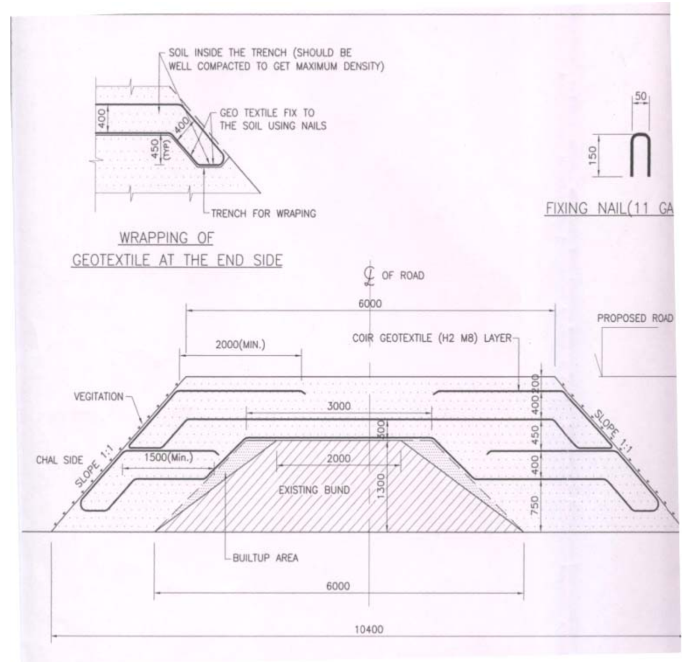


Fig.4. Design of geotextile reinforced farm road

## RECOMMENDATIONS FOR CONSTRUCTION

Prepare a level foundation/ surface in accordance with the design parameters. Prior to installation of geotextiles, the subgrade/ slope should be raked or graded to an even surface, free of depressions or projections. Obstructions, which can damage the geotextiles, should be removed. Erect temporary formwork to the face angle if needed [Beena, 2007]. The coir geotextiles are coming in rolls and spread it and cut into required length. Position the bottom layer of reinforcement with sufficient allowance at the face for wrap around and turn back into the fill. The geotextiles should be always in intimate contact with the soil surface of the slope / subgrade. Proper fixing of the geotextiles should be done using fixing nails at 1.0 to 1.5m intervals. Wooden pegs can be used as shown in Fig.6. There should not be any joint of geotextile along the transverse direction across the bund. In the longitudinal direction along the bund, a minimum overlap of 300mm should be provided and should be properly fixed using fixing nails at 300mm.

Special care should be taken while laying the geotextiles along the curved alignment. Care should be taken to see that there is no loss of fill through the face. The fill should be deposited, spread, leveled and compacted in horizontal layers of appropriate thickness as described in the standard specifications for road works and in accordance with the following recommendations: [Beena, 2006]

(i) The deposition and compaction should be carried out so that all layers of coir geotextiles are fixed at the recommended levels on top of the compacted fill.

(ii) Care should be taken to ensure that the coir geotextiles are not damaged or displaced.

(iii) Filling should be done so that no machines or vehicles run on the geotextile. The construction traffic should not pass over the reinforcements before a minimum thickness of 150mm of fill has been placed.

(iv) No portion of the geotextiles should be exposed out.

## FIELD IMPLEMENTATION

Some of the photographs for the field implementation are shown below. In actual field execution due to financial constrains of the project, only one layer of coir geotextile was provided and the bottom folded portion is folded back to the middle height of the filled earth with sufficient overlap of 2m.

Fig.5. Prepared bed before laying geotextile

Fig.6. Coir Geotextile comes in roll and the bamboo nail

Fig.7. Geotextile layer over the subgrade

Fiig. 8. Bamboo pegs inserted to keep the geotextile in position

Fig.9. Fill over geotextile

Fig. 10. Laying along curved alignment

Fig. 11. Roll of geotextile to be wrap around

SUMMARY

A brief review of coir geotextiles, its potentialities, advantages, application area has been presented here. The documented field studies in this area are very less though there is number of applications in this field, mainly due to the fact that these are employed in small scale applications. A few case studies available in literature is reviewed here.

A case study of a farm road of 1.4km long, in which the author was the geotechnical consultant, is described in detail.
It is observed that after 5 years of seasonal changes and traffic usage, the road remains pucca without any damage.

From these it can be observed that potentialities of coir geotextiles are very high and is not fully utilised for the advancement of geotechnical engineering. For that, a systematic study on these material, problem specific, is required both in laboratory and in field. Also specifications should be standardised, which is lacking in the industry.

ACKNWOLEDGEMENT

Author wishes to acknowledge the help and support rendered by the authorities of Kerala State Land Development Corporation, during the project implementation with a special mention to Sri. Bhaskaran. Also the assistance provided by the Laboratory technical assistants of Geotechnical Engineering Laboratory of School of Engineering, Cochin University of Science and Technology are greatly acknowledged.

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